SECTION 5

DRAINAGE SYSTEM DESIGN REQUIREMENTS

SECTION 5 – DRAINAGE SYSTEM DESIGN REQUIREMENTS

5.01 GENERAL:

A. This section contains the minimum storm drainage design criteria to be followed in the design of storm drainage facilities and demonstrates the design procedures to be used on drainage projects in the City of Frisco. All drainage systems shall be designed to accommodate the flow from the one-hundred (100) year frequency storm or the flood of record, whichever is greater.

B. "Director of Engineering Services" shall refer to the Director of Engineering Services or his/her designee.

C. Sizes and grades for storm sewers shall be as required by the Director of Engineering Services, and shall be designed for future development.

D. Burlington Northern Santa Fe Railroad, Texas Department of Transportation, and North Texas Tollway Authority crossings, etc., shall be as approved by the Director of Engineering Services and the respective agency. Permits to agencies other than the city must be submitted through the city.

E. Profile elevations with hydraulic information shall be provided for all mains and laterals.

F. Storm sewer lines shall be sized and extended through the limits of a development to serve adjacent properties. In phased construction of thoroughfares, the storm sewer lines shall be extended the entire length of the thoroughfare being constructed.

G. All grades shall be shown to the nearest one-hundredth of a foot (0.01') and shall be based on NAVD 88 datum.

H. Construction Staking - Line and grade stakes for construction of all mains and laterals shall be furnished by the developer's Engineer or their designated representative. The City will not be liable for improper alignment or delay of any kind caused by improper or inadequate surveys by the developer or by interference of any other utilities, public or franchise.

5.02 METHODS OF DETERMINING DESIGN DISCHARGE:

A. Rational Formula – This formula shall be used for computing storm water runoff for hydraulic design of facilities serving a drainage area less than two hundred (200) acres

1. The Rational Formula for computing peak runoff rates is as follows:

$$Q = C*I*A$$

Where Q = Runoff rate in cubic feet per second.
C = Runoff use coefficient, dimensionless.
I = Rainfall intensity in inches per hour.
A = Drainage area in acres.

2. All runoff calculations shall be based upon a fully developed watershed and ultimate land use as shown on the City of Frisco Comprehensive Plan or existing zoning, whichever is greater. Larger coefficients shall be used if considered by the Director of Engineering Services to be appropriate to the project. Runoff coefficients "C" for various land uses are shown in Table 5.1.

3. The rainfall intensity value "I", based on the National Weather Service Rainfall Frequency Data presented in Technical Memorandum NWS Hydro-35, dated June 1977 (2 to 100 year) and US Geologic Survey Frequency Data presented in Water Resources Investigations Report 98-4044, dated 1998 (500 year) and is provided in Figure 5.1 and Table 5.2. The intensity for a duration equal to the time concentration (T_C) can be obtained from Table 5.1. In no case shall the inlet time (T_C for determining Q to an inlet) be more than the time shown in Table 5.1.

4. Calculations for inlet time (T_c) should include time for overland, gutter and/or channel flow where applicable. T_C's for points along the enclosed storm drain system may include travel time in pipe in addition to inlet time.

TABLE 5.1 – Values for Runoff Coefficient, Inlet Time and Rainfall Intensity

Land Use (Zoning)	**Runoff Coefficient "C"**	**Inlet Time "T_C" (Minutes)**	**Rainfall Intensity "I" (Inches per Hour)**
Low-Density Residential (RE, SF-1)	0.50	15	7.52
Medium-Density Residential (SF-2 thru SF-5, OTR, MH)	0.55	15	7.52
Two Family, Patio Home, Town Home (2F, PH, TH)	0.70	15	7.52
Multiple Family (MF-1, MF-2)	0.80	10	8.74
Non-Residential Uses (O, NS, R, OTC, C, H, CO, IT, I)	0.90	10	8.74
Park Area (no developable land)	0.35	15	7.52
School	0.70	15	7.52
Church	0.80	10	8.74
Hospital	0.90	10	8.74
Type A and B Thoroughfares	0.90	10	8.74

NOTE: Contiguous platted open space areas greater than three (3) acres in Alternative Subdivision Designs may use the runoff coefficient for Park Areas.

FIGURE 5.1: RAINFALL INTENSITY CURVES

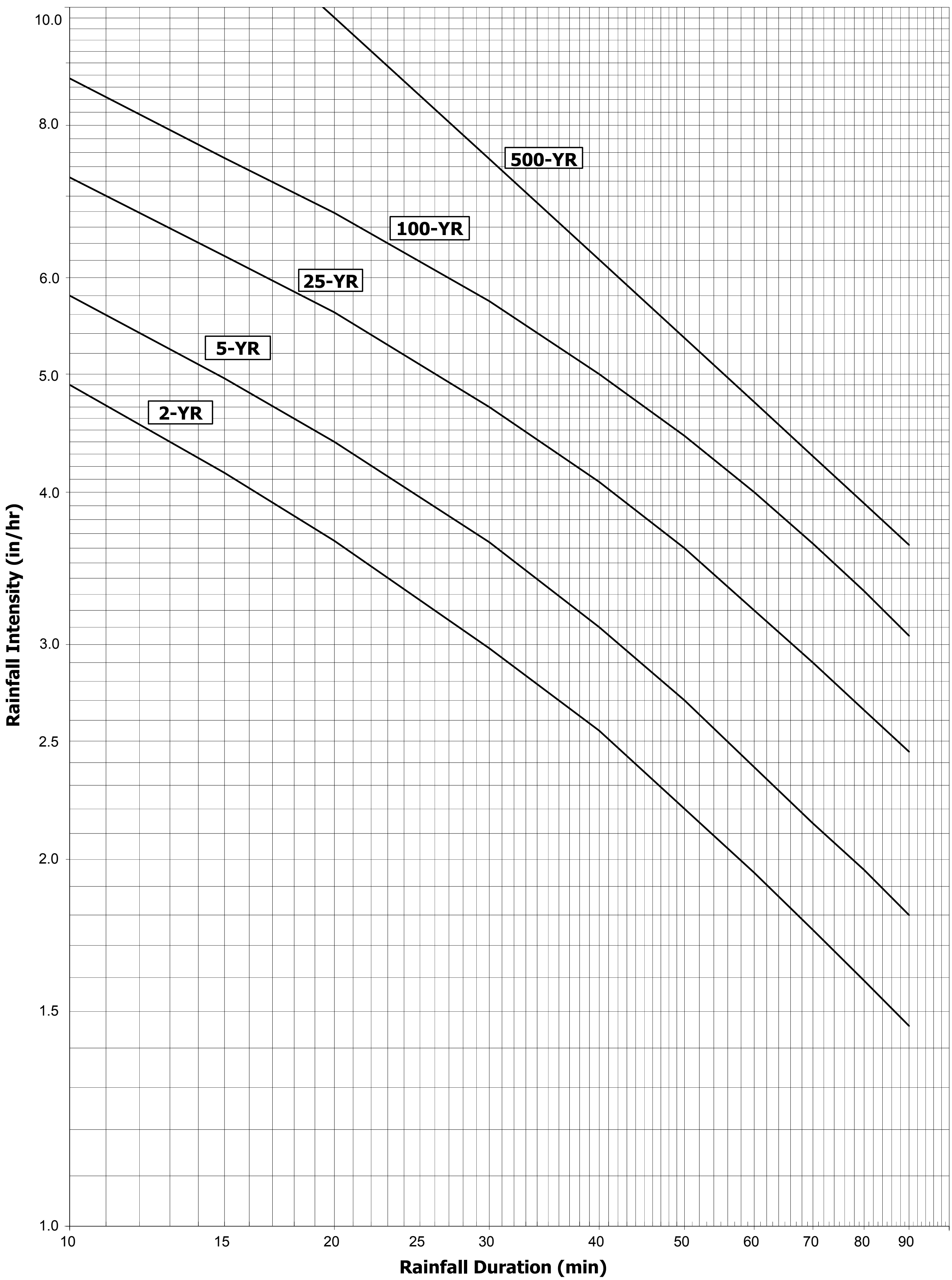


TABLE 5.2 – Rainfall Intensity Values

Storm Freq. (yrs)	Rainfall Intensity (in/hr) Storm Duration (min)									
	10	**15**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
2	4.90	4.15	3.65	2.98	2.55	2.20	1.95	1.75	1.59	1.46
5	5.80	4.96	4.40	3.64	3.10	2.70	2.38	2.14	1.96	1.80
25	7.25	6.25	5.62	4.70	4.08	3.60	3.20	2.90	2.65	2.45
100	8.74	7.52	6.78	5.74	5.00	4.45	4.00	3.63	3.32	3.05
500	15.40	11.84	9.81	7.51	6.21	5.35	4.74	4.28	3.92	3.62

B. Unit Hydrograph Method – For drainage area in excess of two hundred (200) acres the unit hydrograph method shall be utilized.

1. The use of a unit hydrograph calculation will be based upon standard and accepted Engineering Principles normally used in the profession subject to the approval of the Director of Engineering Services. Acceptable methods include the Soil Conservation Services (SCS) Technical Release Number 55 for drainage areas two hundred (200) acres to two thousand (2,000) acres, and SCS's Technical Release Number 20 or the United States Army Corps of Engineers HEC-1 or HEC-HMS models for drainage areas two hundred (200) acres or more.

2. The post development unit hydrograph method shall be based upon fully developed watershed conditions assuming no effects from the small on-site detention facilities for maintaining peak rate of runoff as if the property was developed as single family. The detention effects of large regional detention facilities can be taken into account in unit hydrograph methods.

3. Circumstances that may require the use of a unit hydrograph method include open channels, reclaiming floodplains, creating lakes, regional detention/retention facilities or building other types of drainage related facilities on major drainage courses. Design engineers of these types of facilities should be aware that designing for fully developed watershed conditions will require calculation of fully developed flows instead of flows used from the Federal Emergency Management Agency's (FEMA) flood insurance studies for the City of Frisco. FEMA's flows cannot be used because the flows are based upon existing watershed conditions.

C. Detention Effects – Storm sewer downstream of detention ponds shall be designed to convey the pond's allowable release rate.

5.03 STREET CAPACITY:

A. Straight Crown Streets:

1. All straight crown street capacities shall be hydraulically designed using Manning's equation:

$$Q = (1.486/n)*A*(R^{2/3})*(S^{1/2})$$

Where:

Q = Gutter flow in cubic feet per second.
n = Roughness coefficient, (0.0175 for concrete street).
A = Cross section flow area in square feet.
R = Hydraulic radius of the conduit in feet, which is the area of the flow divided by the wetted perimeter (R=A/P).
P = Wetted perimeter in feet.
S = Slope of the hydraulic gradient in feet per feet.

2. Type A and B thoroughfares shall have a minimum cross slope of one-quarter inch (1/4″) per foot and a maximum cross slope of three-eighths inch (3/8″) per foot.

3. As water collects in the street gutter and flows downhill, a portion of the roadway is flooded. During a one hundred (100) year storm event, the City of Frisco requires a minimum of nine feet (9′) of pavement in each direction for twenty-four foot (24′) sections and twenty-one feet (21′) of pavement in each direction for thirty-six foot (36′) sections to remain dry for Type A and B thoroughfares. Inserting the slope (S, feet/feet) into the flow equations in Table 5.3, based on type of thoroughfare and paving section, will provide capacity for streets to comply with City of Frisco requirements.

TABLE 5.3 – Capacity of Straight Crown Streets

Type of Thoroughfare	Cross Fall / Crown Height	Street Capacity (Cubic Feet per Second)	Depth in Gutter (Inches)
A, B (24′)	1/4″ per foot cross fall	$Q=57.73*(S^{1/2})$	3.75″
A, B (24′)	3/8″ per foot cross fall	$Q=113.44*(S^{1/2})$	5.63″
A (36′)	1/4″ per foot cross fall	$Q=57.73*(S^{1/2})$	3.75″
A (36′)	3/8″ per foot cross fall	$Q=113.44*(S^{1/2})$	5.63″

B. Parabolic Crown Streets:

1. All parabolic crown street capacities shall be hydraulically designed using Manning's equation as shown in Section 5.03.A.1.

2. Type C and D thoroughfares shall have six inch (6″) parabolic crowns, Type E thoroughfares a four inch (4″) parabolic crown and Type F thoroughfares a five inch (5″) parabolic crown.

3. As water collects in the street gutter and flows downhill, a portion of the roadway is flooded. During a one hundred (100) year storm event, the gutter depth on Type C, D, E, and F thoroughfares are required by the City of Frisco not to exceed six inches (6″) or top of curb, whichever is less. Inserting the slope (S, feet/feet) into the flow equations in Table 5.4, based on type of thoroughfare and paving section, will provide capacity for streets to comply with City of Frisco requirements.

TABLE 5.4 – Capacity of Parabolic Crown Streets

Type of Thoroughfare	Cross Fall / Crown Height	Paving Section (Curb Face to Curb Face)	Street Capacity (Cubic Feet per Second)	Street Capacity to Crown (Cubic Feet per Second)	Gutter Capacity (Cubic Feet per Second)
C, D	6″ crown	36′	$Q=151.46*(S^{1/2})$	$Q=151.46*(S^{1/2})$	$Q=75.73*(S^{1/2})$
E	4″ crown	26′	$Q=254.43*(S^{1/2})$	$Q=55.71*(S^{1/2})$	$Q=27.85*(S^{1/2})$
F	5″ crown	30′	$Q=203.13*(S^{1/2})$	$Q=93.14*(S^{1/2})$	$Q=46.57*(S^{1/2})$

5.04 ALLEY CAPACITY:

A. All alley capacities shall be hydraulically designed using Manning's equation as shown in Section 5.03.A.1.

B. In residential areas where the standard alley section capacity is exceeded, storm sewer systems with inlets shall be provided. The alley capacity can be obtained by inserting in the slope of the alley into the flow equations provided in Table 5.5.

C. Alleys shall be designed with a five inch (5″) invert in twelve feet (12′) of pavement.

TABLE 5.5 – Capacity of Alleys

Type of Alley	Street Capacity (Cubic Feet per Second)
Lots Adjacent are Higher than Alley	$Q=208.53*(S^{1/2})$
Lot Adjacent is Lower than Alley	$Q=74.48*(S^{1/2})$

5.05 VALLEY GUTTERS:

A. The use of valley gutters to convey storm water across a street intersection is subject to the following criteria:

1. Valley gutters shall not cross Type A, B, C, and D thoroughfares.

2. At any intersection, perpendicular valley gutters will not be permitted; and parallel valley gutters may cross only the lower classified street.

5.06 INLET LOCATION AND CAPACITY:

A. Curb inlets shall be placed to ensure that the one hundred (100) year flow in a street does not exceed the dry lane requirements for straight crown streets and top-of-curb elevation for parabolic crown streets as per Sections 5.03.A.3 and 5.03.B.3. Table 5.6 shall be provided within the engineering plans for review by City staff.

B. If in the judgment of the Director of Engineering Services the flow in the gutter is still excessive, the storm sewer shall be extended to a point where the gutter flow can be effectively intercepted by curb inlets. The following is a list of guidelines for curb inlet placement:

1. Placing several curb inlets at a single location is only permitted in areas with steep grades (4% or greater) in order to prevent flooding and avoid exceeding street capacity in flatter reaches downstream.

2. To minimize water draining through an intersection, curb inlets should be placed upgrade from an intersection.

3. Curb inlets, when required, shall be placed upstream from right angle turns and street intersections.

4. Any discharge of concentrated flow into streets and alleys requires a hydraulic analysis of street and alley capacities.

5. Design of sag inlets shall include a check for inlet control at the entrance to the lateral.

6. Curb inlets at sag points require a minimum ten foot (10′) opening and shall have a minimum twenty-one inch (21″) lateral.

7. Curb inlets at sag points on roadways other than Type A and B thoroughfares must have a paved overflow that prevents water from rising more than nine-tenths of a foot (0.9′) above the street gutter. If the overflow is located between lots, it shall be a paved flume in a drainage easement on one lot. The overflow flume shall be four feet (4′) wide with a four inch (4″) invert.

8. Sag inlets on Type A and B thoroughfares shall have an emergency overflow inlet within three-tenths of a foot (0.3′) vertically or thirty feet (30′) horizontally, whichever is greater.

9. The end of the curb inlet box shall be at least ten feet (10′) on the uphill side and five feet (5′) on the downhill side from a curb return or driveway wing and the curb inlet shall be located to minimize interference with the use of adjacent property. Curb inlets shall not be located across from median openings where a driveway may be added.

10. Curb inlets shall not be located directly above storm drain lines.

11. Curb inlet depth shall not be less than four feet (4′) or greater than four and a half feet (4.5′) for all public improvements.

12. Data shown for each curb inlet shall include paving or storm sewer stationing at centerline of curb inlet, size of curb inlet, type of curb inlet, top-of-curb elevation and flow line elevation of curb inlet. Flow to curb inlet and bypass flow, if applicable, shall be shown to each inlet on storm sewer plan.

13. Double inlets shall not be allowed.

14. Inlets are required at the low point of a superelevation to prevent flow across the roadway.

15. Curb inlets shall not be located at the PC or PT of a curve.

16. Multiple sag inlets shall be located no closer than three-hundred feet (300′).

C. In situations where only the lower portion of an enclosed storm sewer system is being built, stub-outs for future connections must be included. In this case, it is not necessary to capture all the street flow at the stub-out. As a minimum, there must be enough inlets to capture an amount equal to the total street flow capacity at the stub-out.

D. In determining curb inlet capacity, the City of Frisco requires that curb inlets on streets with grades shall be sized using the capacities provided in Tables 5.7 and 5.8.

E. Grate combination inlets shall be located in alleys upgrade from an intersection and where necessary to prevent water from entering intersections in amounts exceeding allowed street capacity. Capacities for grate combination inlets are provided in Tables 5.9 through 5.12.

F. Combination inlets are required in alleys and they shall have their gutter two-tenths of a foot (0.2′) lower than the alley invert for a typical twelve foot (12′) alley. Additional lowering of the inlet will be required if the inlet is more than six feet (6′) from the invert of the alley.

G. Drop inlets or wye ("Y") inlets shall be located to collect water on non-paved areas where it is not practical to use a headwall. The depth of a "Y" inlet shall not exceed five feet (5′). No double "Y" inlets shall be allowed. Capacities for "Y" inlets are shown in Table 5.13.

H. Capacity calculations for curb inlets located in a non-residential private drainage system shall be provided by the design engineer and approved by the City.

I. Bio-filters are an option if located in non-residential developments and outside of City Easements and Rights-of-Way.

TABLE 5.6 – Inlet Design Calculations

INLET		Design Storm Freq. (years)	AREA RUNOFF: Q=CIA					Carry-Over from Upstream Inlet (cfs)	Total Gutter Flow (cfs)	Gutter Capacity (cfs)	Gutter Slope (ft/100 ft)	Crown Type	SELECTED INLET			Carry-Over to Downstream Inlet (cfs)
No.	Location		Tc (min)	Intensity "I" (in/hr)	Runoff Coeff. "C"	Area "A"	Q (cfs)						Length Li (ft)	Type	Inlet Capacity (cfs)	

TABLE 5.7 – Capacity of Inlets for Straight Crown Streets

RECESSED AND STANDARD ON GRADE CURB INLET (1/4″ per Foot Cross Slope)			RECESSED AND STANDARD ON GRADE CURB INLET (3/8″ per Foot Cross Slope)		
Inlet Length	Gutter Slope	Inlet Capacity	Inlet Length	Gutter Slope	Inlet Capacity
8′	6%	3.8 cfs	8′	6%	4.0 cfs
8′	3%	4.0 cfs	8′	3%	4.3 cfs
8′	2%	4.2 cfs	8′	2%	4.5 cfs
8′	1%	4.4 cfs	8′	1%	4.8 cfs
8′	0.6%	4.7 cfs	8′	0.6%	5.2 cfs
10′	6%	4.8 cfs	10′	6%	5.2 cfs
10′	3%	5.1 cfs	10′	3%	5.6 cfs
10′	2%	5.4 cfs	10′	2%	6.0 cfs
10′	1%	5.7 cfs	10′	1%	6.4 cfs
10′	0.6%	6.2 cfs	10′	0.6%	6.9 cfs
12′	6%	6.0 cfs	12′	6%	6.5 cfs
12′	3%	6.4 cfs	12′	3%	7.0 cfs
12′	2%	6.8 cfs	12′	2%	7.5 cfs
12′	1%	7.3 cfs	12′	1%	8.2 cfs
12′	0.6%	7.8 cfs	12′	0.6%	8.7 cfs

Notes:
1. Sag inlets will be designed to accept no more than two (2) cfs per foot of opening.
2. Inlet capacities for other gutter slopes not listed may be interpolated.

TABLE 5.8 – Capacity of Inlets for Parabolic Crown Streets

STANDARD ON GRADE CURB INLET (6″ Parabolic Crown)			STANDARD ON GRADE CURB INLET (5″ Parabolic Crown)			STANDARD ON GRADE CURB INLET (4″ Parabolic Crown)		
Inlet Length	Gutter Slope	Inlet Capacity	Inlet Length	Gutter Slope	Inlet Capacity	Inlet Length	Gutter Slope	Inlet Capacity
8′	6%	4.2 cfs	8′	6%	4.2 cfs	8′	6%	4.1 cfs
8′	3%	4.5 cfs	8′	3%	4.5 cfs	8′	3%	4.4 cfs
8′	2%	4.8 cfs	8′	2%	4.8 cfs	8′	2%	4.6 cfs
8′	1%	5.2 cfs	8′	1%	5.2 cfs	8′	1%	5.0 cfs
8′	0.6%	5.6 cfs	8′	0.6%	5.6 cfs	8′	0.6%	5.3 cfs
10′	6%	5.6 cfs	10′	6%	5.6 cfs	10′	6%	5.3 cfs
10′	3%	6.0 cfs	10′	3%	6.0 cfs	10′	3%	5.7 cfs
10′	2%	6.5 cfs	10′	2%	6.5 cfs	10′	2%	6.1 cfs
10′	1%	7.0 cfs	10′	1%	7.0 cfs	10′	1%	6.6 cfs
10′	0.6%	7.5 cfs	10′	0.6%	7.5 cfs	10′	0.6%	7.1 cfs
12′	6%	7.0 cfs	12′	6%	7.0 cfs	12′	6%	6.6 cfs
12′	3%	7.5 cfs	12′	3%	7.5 cfs	12′	3%	7.2 cfs
12′	2%	8.2 cfs	12′	2%	8.2 cfs	12′	2%	7.5 cfs
12′	1%	9.0 cfs	12′	1%	9.0 cfs	12′	1%	8.4 cfs
12′	0.6%	9.6 cfs	12′	0.6%	9.6 cfs	12′	0.6%	9.0 cfs

Notes:
1. Sag inlets will be designed to accept no more than two (2) cfs per foot of opening.
2. Inlet capacities for other gutter slopes not listed may be interpolated.

TABLE 5.9 – Capacity of Two Grate Combination Inlet on Grade

Flow (Cubic Feet per Second)	Gutter Slope					Flow (Cubic Feet per Second)	Gutter Slope				
	0.6%	1.0%	2.0%	3.0%	6.0%		0.6%	1.0%	2.0%	3.0%	6.0%
1						10	62%	61%	61%	60%	59%
1.5	84%	83%				11	61%	61%	60%	59%	58%
2	78%	77%				12	61%	60%	59%	58%	57%
2.5	75%	74%	73%	73%		13	60%	59%	58%	57%	56%
3	73%	72%	71%	70%	70%	14	59%	58%	57%	56%	56%
3.5	72%	71%	69%	68%	68%	15	58%	58%	57%	56%	56%
4	70%	69%	68%	68%	67%	20	57%	56%	56%	55%	54%
5	68%	67%	67%	66%	65%	25		54%	54%	54%	54%
6	67%	66%	65%	64%	63%	30			54%	54%	54%
7	65%	64%	64%	63%	62%	35				54%	53%
8	64%	63%	62%	62%	61%	40				53%	53%
9	63%	63%	62%	61%	60%	45				52%	52%

Notes:
1. Capacity percentages not listed may be interpolated.

TABLE 5.10 – Capacity of Three Grate Combination Inlet on Grade

Flow (Cubic Feet per Second)	Gutter Slope					Flow (Cubic Feet per Second)	Gutter Slope				
	0.6%	1.0%	2.0%	3.0%	6.0%		0.6%	1.0%	2.0%	3.0%	6.0%
1	100%	100%				10	69%	67%	66%	65%	64%
1.5	100%	100%				11	68%	67%	65%	64%	63%
2	93%	90%	87%	86%		12	67%	66%	64%	63%	62%
2.5	90%	87%	84%	81%		13	66%	65%	64%	63%	61%
3	86%	83%	79%	77%	75%	14	66%	64%	63%	62%	60%
3.5	83%	80%	76%	75%	73%	15	65%	64%	62%	61%	59%
4	81%	78%	75%	73%	71%	20	62%	61%	59%	59%	58%
5	77%	75%	73%	71%	70%	25	59%	58%	57%	57%	56%
6	75%	73%	71%	69%	68%	30		57%	57%	56%	56%
7	73%	71%	69%	68%	67%	35			56%	56%	54%
8	71%	69%	68%	67%	66%	40			55%	55%	54%
9	70%	68%	67%	66%	64%	45				54%	53%

Notes:
1. Capacity percentages not listed may be interpolated.

TABLE 5.11 – Capacity of Four Grate Combination Inlet on Grade

Flow (Cubic Feet per Second)	Gutter Slope 0.6%	1.0%	2.0%	3.0%	6.0%	Flow (Cubic Feet per Second)	Gutter Slope 0.6%	1.0%	2.0%	3.0%	6.0%
1	100%					10	75%	73%	70%	68%	67%
1.5	100%	100%				11	74%	72%	69%	68%	67%
2	100%	100%	97%	96%		12	74%	70%	67%	66%	66%
2.5	98%	97%	95%	87%		13	73%	70%	67%	66%	65%
3	96%	95%	85%	83%	80%	14	71%	69%	66%	65%	64%
3.5	95%	89%	83%	81%	78%	15	70%	68%	66%	65%	64%
4	90%	85%	81%	79%	77%	20	67%	66%	63%	62%	59%
5	84%	81%	78%	76%	75%	25		64%	61%	60%	58%
6	82%	79%	76%	74%	73%	30		62%	60%	58%	57%
7	80%	77%	74%	73%	71%	35		61%	59%	57%	56%
8	80%	76%	73%	71%	69%	40			58%	57%	56%
9	76%	74%	71%	70%	68%	45				56%	55%

Notes:
1. Capacity percentages not listed may be interpolated.

TABLE 5.12 – Capacity of Grate Combination Inlet at Low Point

Grate Combination Inlet Size	Max. Depth of Flow (Feet)	Inlet Cap.	Grate Combination Inlet Size	Max. Depth of Flow (Feet)	Inlet Cap.	Grate Combination Inlet Size	Max. Depth of Flow (Feet)	Inlet Cap.
2	0.6	15 cfs	3	0.6	22 cfs	4	0.6	29 cfs
2	0.5	13 cfs	3	0.5	18 cfs	4	0.5	24 cfs
2	0.4	10 cfs	3	0.4	15 cfs	4	0.4	20 cfs
2	0.3	8 cfs	3	0.3	12 cfs	4	0.3	16 cfs
2	0.2	6 cfs	3	0.2	9 cfs	4	0.2	11 cfs

TABLE 5.13 – Capacity of "Y" Inlets

Standard Drop Inlet Size	Max. Depth of Flow (Feet)	Inlet Capacity	Standard Drop Inlet Size	Max. Depth of Flow (Feet)	Inlet Capacity	Standard Drop Inlet Size	Max. Depth of Flow (Feet)	Inlet Capacity
2′ X 2′	1.0	22 cfs	3′ X 3′	1.0	33 cfs	4′ X 4′	1.0	44 cfs
2′ X 2′	0.9	19 cfs	3′ X 3′	0.9	28 cfs	4′ X 4′	0.9	37 cfs
2′ X 2′	0.8	16 cfs	3′ X 3′	0.8	23 cfs	4′ X 4′	0.8	32 cfs
2′ X 2′	0.7	14 cfs	3′ X 3′	0.7	19 cfs	4′ X 4′	0.7	26 cfs
2′ X 2′	0.6	10 cfs	3′ X 3′	0.6	15 cfs	4′ X 4′	0.6	20 cfs
2′ X 2′	0.5	8 cfs	3′ X 3′	0.5	12 cfs	4′ X 4′	0.5	16 cfs
2′ X 2′	0.4	6 cfs	3′ X 3′	0.4	8 cfs	4′ X 4′	0.4	11 cfs
2′ X 2′	0.3	4 cfs	3′ X 3′	0.3	5 cfs	4′ X 4′	0.3	7 cfs
2′ X 2′	0.2	2 cfs	3′ X 3′	0.2	3 cfs	4′ X 4′	0.2	4 cfs

5.07 DESIGN OF ENCLOSED STORM SEWER SYSTEM:

A. Runoff from paved areas being discharged into natural creeks or channels shall be conveyed through enclosed storm sewer systems.

B. All enclosed systems shall be hydraulically designed. Table 5.14 shall be provided within the engineering plans for review by City staff. The hydraulic gradient and full-flow velocity shall be calculated using the design flow, appropriate pipe size, and Manning's equation:

$$Q = (1.486/n)*A*(R^{2/3})*(S^{1/2})$$

Where:	Q	=	Runoff rate in cubic feet per second.
	A	=	Cross sectional area of the conduit in square feet.
	n	=	Roughness coefficient, (0.013 for concrete pipe and box culverts).
	R	=	Hydraulic radius of the conduit in feet, which is the area of the flow divided by the wetted perimeter (R=A/P).
	S	=	Slope of the hydraulic gradient in feet per feet.

C. Starting Hydraulic Gradient:

1. After computing the runoff rate to each inlet as discussed in Section 5.06, the size and gradient of pipe required to convey the design storm must be determined. The City of Frisco requires that all hydraulic gradient calculations begin at the outfall of the system. The following are criteria for the starting elevation of the hydraulic gradient:

   a. Starting hydraulic grade at an outfall into a creek or channel should be the one hundred (100) year fully developed water surface unless an approved flood hydrograph is available to provide a coincident flow elevation for the system's peak.

   b. When a proposed storm sewer is to connect to an undersized existing storm sewer system, calculation of the hydraulic gradient for the proposed storm sewer shall start at the outfall of the existing storm sewer system.

D. Lateral Design:

1. The hydraulic grade line shall be calculated for all proposed laterals and inlets, and for the existing laterals being connected into a proposed drainage system.

2. Laterals shall intersect the storm drain at a sixty degree (60°) angle. Connecting more than one lateral into a storm drain at the same joint localizes head losses; however, a manhole or junction structure must be provided. An exception to this rule may be considered when the diameter of the main line is more than twice as great as the diameter of the largest adjoining lateral.

3. Laterals shall not connect into downstream inlets.

4. All "Y" inlets and curb inlets ten feet (10') or larger shall have twenty-one inch (21") laterals as a minimum. All other curb inlets shall have eighteen inch (18") laterals as a minimum. Laterals shall be designed with future developed conditions in mind to facilitate extensions and increased flows.

TABLE 5.14 – Storm Sewer Calculations

RUNOFF COLLECTION POINT (Inlet or Manhole)		Distance Between Collection Points	INCREMENTAL DRAINAGE AREA				Accum-ulated "CA"	Time at Upstream Station (minutes)	Design Storm Frequency (years)	Intensity "I" (in/hr)	Storm Water Runoff "Q" (cfs)	Slope of Hydraulic Gradient "S" (ft/ft)	Selected Storm Sewer Size	Velocity in Sewer Between Connection Points "V" (fps)	Velocity Head Loss at Upstream Station	Head Loss Coeff. Kj	Inlet, Manhole, Bends or Junction Box Losses	Flow Time in Sewer (minutes)	Time at Downstream Station (minutes)	Remarks
Upstream Station	Downstream Station		Area No.	Drainage Area "A" (acres)	Runoff Coeff. "C"	Incremental "CA"														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

E. Velocity Head Losses:

1. Adjustments are made in the hydraulic grade line whenever the velocity in the main changes due to conduit size changes or discharge changes. Laterals in partial flow must be designed appropriately.

2. In determining the hydraulic gradient for the lateral, begin with the hydraulic grade of the trunk line at the junction plus the H_L due to the velocity change. Where the lateral is in full flow, the hydraulic grade is projected along the friction slope calculated using Manning's Equation.

3. Hydraulic grade line "losses" or "gains" for wyes, pipe size changes, and other velocity changes will be calculated by the following formulas:

   $V_1 < V_2$: $H_L = [(V_2)^2/(2*g)]-[(V_1)^2/(2*g)]$ $V_1 > V_2$: $H_L = [(V_2)^2/(4*g)]-[(V_1)^2/(4*g)]$

   Where: H_L = Hydraulic grade line loss or gain, feet.
   V_1 = Upstream velocity, feet per second.
   V_2 = Downstream velocity, feet per second.
   g = Gravity constant (32.2 feet per second^2).

4. Head losses for pipe in full flow at manholes, bends, and inlets, where the flow quantity remains the same, shall be calculated as follows:

   $H_L = K_j*[(V)^2/(2*g)]$

   Where: H_L = Hydraulic grade line loss or gain, feet.
   V = Velocity in the lateral, feet per second.
   g = Gravity constant (32.2 feet per second^2).
   K_j = Coefficient of loss per Table 5.15.

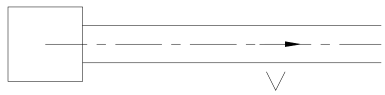
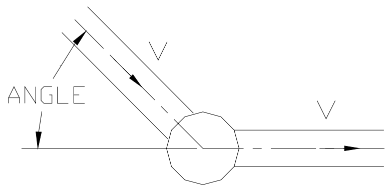
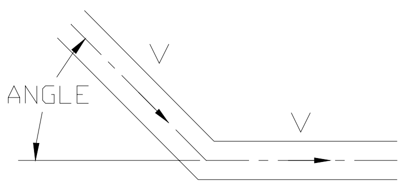
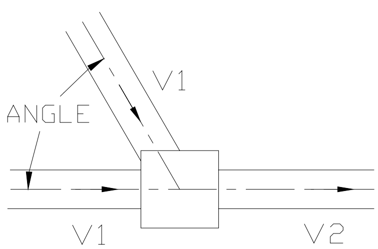
   The hydraulic grade line within the inlet should be a minimum of one foot (1′) below the top of the inlet.

5. Head losses or gains at manholes and junction boxes where there is an increase in flow quantity shall be calculated as follows:

   $H_L = [(V_2)^2/(2*g)]-K_j*[(V_1)^2/(2*g)]$

   Where: H_L = Hydraulic grade line loss or gain, feet.
   V_1 = Upstream velocity, feet per second.
   V_2 = Downstream velocity, feet per second.
   g = Gravity constant (32.2 feet per second^2).
   K_j = Coefficient of loss per Table 5.15.

TABLE 5.15 – Velocity Head Loss in Closed Conduits

Inlet		
Schematic		**Kj**
		1.25
Manhole at Change in Pipe Direction		
Schematic	**Angle**	**Kj**
	90°	0.55
	60°	0.48
	45°	0.42
	30°	0.30
	0°	0.05
Bend in Pipe		
Schematic	**Angle**	**Kj**
	45°	0.35
	30°	0.20
Manhole		
Schematic	**Angle**	**Kj**
	0°	1.00
	22 1/2°	0.75
	45°	0.50
	60°	0.35
	90°	0.25

F. Storm Sewer:

1. Alignments of proposed storm sewer systems should utilize existing easements and rights-of-way. If located within an easement, the storm sewer shall be centered within the easement. If located under paving within rights-of-way, the centerline of the storm sewer shall be located under paving seven feet (7’) from the outside back of curb. No part of the storm sewer is to be designed within the improved subgrade of a proposed pavement.

2. Horizontal and vertical curve design for storm sewers shall take into account joint closure. Half tongue exposure is the maximum opening permitted with tongue and groove pipe. Where vertical and/or horizontal alignment requires greater deflection, radius pipe on curved alignment shall be used.

3. Box culvert pipe shall be designed as if flowing full. Design flow depth of less than full to get a lesser wetted perimeter is not acceptable.

4. End-to-end connections of different size pipes shall match at the crown of the pipes unless utility clearance dictates otherwise.

5. A minimum grade as shown in Table 5.16 will be maintained in the pipe.

TABLE 5.16 – Minimum Grades for Concrete Pipes

Pipe Diameter (Inches)	Slope (Feet/100 Feet)	Pipe Diameter (Inches)	Slope (Feet/100 Feet)
18	0.180	51	0.045
21	0.150	54	0.041
24	0.120	60	0.036
27	0.110	66	0.032
30	0.090	72	0.028
33	0.080	78	0.025
36	0.070	84	0.023
39	0.062	90	0.021
42	0.056	96	0.019
45	0.052	102	0.018
48	0.048	108	0.016

6. Only standard sizes will be used. Pipe sizes shall not be decreased in the downstream direction.

7. Storm sewer systems shall be extended to offsite area(s) that naturally drain across the property being developed.

G. Manhole Placement:

1. The following is a list of guidelines governing the placement of storm sewer manholes to ensure adequate accessibility of storm drainage system:

   a. Storm sewer lines forty-five inches (45″) in diameter or less shall have points of access no more than five hundred feet (500′) apart. A manhole shall be provided where this condition is not met.

   b. Storm sewer lines forty-eight inches (48″) in diameter or larger shall have points of access no more than one thousand feet (1,000′) apart.

   c. A manhole may be required where two or more pipes connect into a main at the same joint. The exception to this rule would be the case in which the diameter of the main line is at least twice a large as the diameter of the largest adjoining pipe. A construction detail may be necessary at such locations.

   d. In selecting a location for a manhole, pipe size changes and junctions are preferred sites. This will localize and minimize head losses.

   e. Manholes are required when bends exceed forty-five degrees (45°).

H. Outfall Design:

1. Each outfall situation shall be considered individually. The following are examples of conditions to be considered when determining the need for energy dissipation:

   a. Elevation of rock.

   b. Normal water surface elevation.

   c. Channel lining.

d. Alignment of pipe to channel.

e. Erosive potential of channel.

2. Creative approaches to engineering design are encouraged in order to produce the most cost effective and environmentally acceptable system as determined by the Director of Engineering Services. As an example, if there is stable rock in a creek bottom, the system could outfall at the rock line or if there is concrete channel lining, the pipe could be brought to the concrete at a reasonable grade so long as it outfalls below the one hundred (100) year water surface in the channel.

3. Discharge flow lines of storm sewers shall be a minimum of two feet (2') above the flow line of creeks and channels unless channel lining is present.

4. The last ten feet (10') of the storm sewer pipe is to be laid on a maximum one percent (1%) grade.

5. Energy dissipation shall be provided when the outfall velocities exceed maximum allowable discharge velocities as shown in Table 5.17.

6. Submerged or partially submerged outlets are allowed provided a dry manhole is constructed upstream of the outlet.

TABLE 5.17 – Maximum Outfall Discharge Velocity

Downstream Channel Material	Maximum Allowable Discharge Velocity (Feet per Second)
Earth unlined vegetated clay soils	7
Earth unlined vegetated sandy soils	5
Dry riprap (ungrouted)	10
Natural rock or finished concrete	15

I. All storm sewer conduits shall be designed for full flow. Design flow depth of less than full to get a lesser wetted perimeter is not acceptable.

5.08 HYDRAULIC DESIGN OF CULVERTS:

A. All culverts, headwalls, wingwalls, and aprons shall be designed in conformity with the City of Frisco Standard Construction Details or the Texas Department of Transportation Details and Standards in the event the City of Frisco does not have a standard construction detail.

B. In sizing culverts, the engineer shall keep head losses and velocities within generally acceptable engineering practices while selecting the most economical structure. This normally requires selecting a structure which creates a slight headwater (<1.2d) condition and has a flow velocity at or below the allowed maximum. Velocities in culverts are normally limited to the maximum allowed in the downstream channel unless there is some form of energy dissipation at the outfall.

C. In the hydraulic design of culverts, an investigation must be made into the type of flow condition through the culvert. The flow will be controlled, or limited, either at the culvert entrance or the outlet, and is designated either inlet or outlet control, respectively.

1. Inlet Control - Exists when the barrel capacity exceeds the culvert inlet capacity, and the tailwater depth and entrance geometry at the inlet will control the amount of water entering the barrel. The roughness, length of culvert barrel, and outlet conditions do not affect capacity for culverts with inlet control.

2. Outlet Control- Exists when the culvert inlet capacity exceeds the barrel capacity or the tailwater elevation causes a backwater effect through the culvert. In this case, the tailwater elevation, slope, length and roughness of the culvert barrel will determine the hydraulic capacity of the culvert even though the entrance conditions are such that a larger flow could be conveyed.

D. Freeboard, the vertical clearance between the design water surface and the top-of-curb, is included as a safety factor in the event of clogging of the culvert. Two feet (2′) of freeboard above the one hundred year (100) water surface elevation is required.

E. Culverts should always be aligned to follow the natural stream channel. Survey information of the stream channel should be provided for one hundred feet (100′) upstream and downstream from the proposed culverts so that the channel alignment is evident.

F. In residential developments, no more than four-barrel box culverts will be permitted for stream crossings, unless otherwise approved by the Director of Engineering Services.

G. To minimize the undesirable backwater effects and erosive conditions produced where the total width of box culverts exceeds the bottom width of the channel, a transition upstream and downstream of the culverts must be provided. The transition should have a minimum bottom width transition of 2 to 1 and include warping of side slopes as required. The 2 to 1 transition is 2 along the centerline of the channel and 1 perpendicular to the centerline.

H. Headwalls and Entrance Conditions:

1. Headwalls and endwalls refer to the entrances and exits of structures, respectively, and are usually formed of cast-in-place concrete and located at either end of the drainage system. Wingwalls are vertical walls, which project out from the sides of a headwall or endwall. The purpose of these structures are:

   a. To retain the fill material and reduce erosion of embankment slopes.

   b. To improve hydraulic efficiency.

   c. To provide structural stability to the culvert ends and serve as a counterweight to offset buoyant or uplift forces.

2. Headwalls, with or without wingwalls and aprons, shall be designed to fit the conditions of the site. The following are general guidelines governing the use of various types of headwalls:

   a. Straight headwalls (Type A) should be used where the approach velocity in the channel is below six (6) feet per second.

   b. Headwalls with wingwalls and aprons (Type B) shall be used where the approach velocity if from six (6) to twelve (12) feet per second and downstream channel protection is recommended.

   c. Special headwall and wingwalls configurations will be required where approach velocities exceed twelve (12) feet per second, and where the flow must be redirected in order to enter the culvert more efficiently.

   d. Design of headwalls shall include a check for inlet control.

3. A table of culvert entrance losses is provided in Table 5.18. The values of the entrance coefficient K_e represent a combination of the effects of entrance and approach conditions. Losses shall be completed using the following formula:

$$H_e = K_e * [V^2/(2*g)]$$

Where:

H_e = Entrance head loss, feet.

K_e = Entrance loss coefficient.

V = Velocity of flow in culvert, feet per second.

g = Gravity constant (32.2 feet per second^2).

TABLE 5.18 – Culvert Entrance Losses

Type of Structure	K_e
Pipe, Concrete	
- projecting from fill, socket and (groove end)	0.2
- projecting from fill, square cut end	0.5
- headwall or headwall and wingwalls: socket end of pipe (groove end)	0.2
- headwall or headwall and wingwalls: square edge	0.5
- headwall or headwall and wingwalls: rounded (radius = 0.0933D)	0.2
- mitered to conform to fill slope	0.7
- beveled edges, 33.7° or 45°	0.2
- side or sloped tapered inlet	0.2
Pipe, or Pipe-Arch	
- projecting from fill (no headwall)	0.9
- headwall or headwall and wingwalls: square edge	0.5
- mitered to conform to fill slope, paved / unpaved slope	0.7
- beveled edges, 33.7° or 45°	0.2
- side or sloped tapered inlet	0.2
Box, Reinforced Concrete	
- headwall parallel to embankment (no wingwalls): squared on three sides	0.5
- headwall parallel to embankment (no wingwalls): rounded on three sides to radius 1/12 barrel dimension on three sides	0.2
- wingwalls at 30° to 75° to barrel: square edged at crown	0.4
- wingwalls at 30° to 75° to barrel: crown edge rounded to radius of 2/12 barrel dimension, or beveled top edge.	0.2
- wingwall at 10° to 25° to barrel: square edged at crown	0.5
- wingwalls parallel (extension of sides): square edged at crown	0.7
- side or slope tapered inlet	0.2

Notes:

1. Where the term "rounded" entrance edge is used, it means a six inch (6") radius on the exposed edge of the entrance.

5.09 OPEN CHANNEL DESIGN:

A. Preservations of creeks and tributaries in their natural condition is preferred with the exceptions that all undesirable brush is removed and the channel sides are stabilized to minimize erosion as approved by the City's Environmental Engineer.

B. Excavated open channels may be used to convey storm waters where the construction cost and/or long-term maintenance cost involved with a closed storm sewer system is not justified economically. Open channels shall be designed to convey the full design discharge. Unpaved gabion channel bottoms shall not be allowed.

C. The maximum slopes and velocities for various types of excavated channels are shown in Table 5.19.

TABLE 5.19 – Maximum Slopes and Velocities for Open Channels

Channel Cover	Maximum Channel Slope (%)	Maximum Side Slope (H:V)	Maximum Velocity (fps)
Bermuda Grass	0-5 5-10 > 10	3:1 3:1 3:1	6 5 4
Buffalo Grass, Kentucky Bluegrass, smooth brome, blue grama	0-5 5-10 > 10	3:1 3:1 3:1	5 4 3
Grass mixture	0-5 5-10*	3:1 3:1	4 3
Lespedeza sericea, weeping love grass, ischaemum (yellow-blue stem), kudzu, alfalfa, crab grass, switchgrass	0-5*	3:1	2.5
Annuals used on mild slopes or as temporary protection until permanent covers are established, common lespedeza, Sudan grass	0-5*	3:1	2.5
Concrete or other non-erodible surface	any	2:1	12
Natural Channels	As determined by geotechnical report		

NOTE: Do not use slopes greater than those indicated by "*".

D. Supercritical flow shall not be allowed in channels except at drop structures and other energy dissipators.

E. At transitions in channel characteristics, velocities must be reduced to the maximum velocity as shown in Table 5.19. Velocities must be reduced before the flow reaches the natural channel using either energy dissipators and/or wider less steep channel. Unlined unvegetated swales are not allowed.

F. Channel armoring for erosion control shall be provided where deemed necessary by the Director of Engineering Services.

G. If the channel cannot be maintained from the top of the bank, a maintenance access ramp shall be provided and included within the drainage easement.

H. Open channels with narrow bottom widths are characterized by high velocities, difficult maintenance, and should be avoided. Minimum channel bottom widths are recommended to be equal to twice the depth. Any permanent open channel with a rock bottom shall have a minimum bottom width of five feet (5′).

I. All open channels require a minimum freeboard of one foot (1′) above the one-hundred (100) year water surface elevation or below top of bank, whichever is greater.

J. The minimum slope for an improved channel is three-tenths of a percent (0.3%).

K. Table 5.20 gives the allowable ranges for roughness coefficients of open channels.

L. Flumes shall not be permitted except for emergency overflow at sag inlets.

M. Pilot channels shall not be permitted in public improvements.

N. Any channel modification must meet the applicable requirements of all State and Federal Regulatory Agencies.

O. If a natural channel is not modified, an erosion hazard setback shall be included within the Drainage and Floodway Easement for the channel. The purpose of this setback is to reduce the potential for any damage to a private lot or street right-of-way caused by the erosion of the bank. The erosion hazard setback shall be determined as follows:

   1. For stream banks composed of material other than rock, locate the toe of the natural stream bank. Construct a 4:1 line sloping away from the bank until it intersects finished grade. From this intersection add fifteen feet (15′) away from the bank. This shall be the limit of the erosion hazard setback.

   2. For stream banks composed partially or entirely of rock, locate the interface of the bank with the top of the unweathered rock strata with the assistance of a geotechnical engineer or geologist. Construct a 3:1 line sloping away from this point until it intersects finished grade. From this intersection add fifteen feet (15′) away from the bank. This shall be the limit of the erosion hazard setback.

TABLE 5.20 – Roughness Coefficients for Open Channels

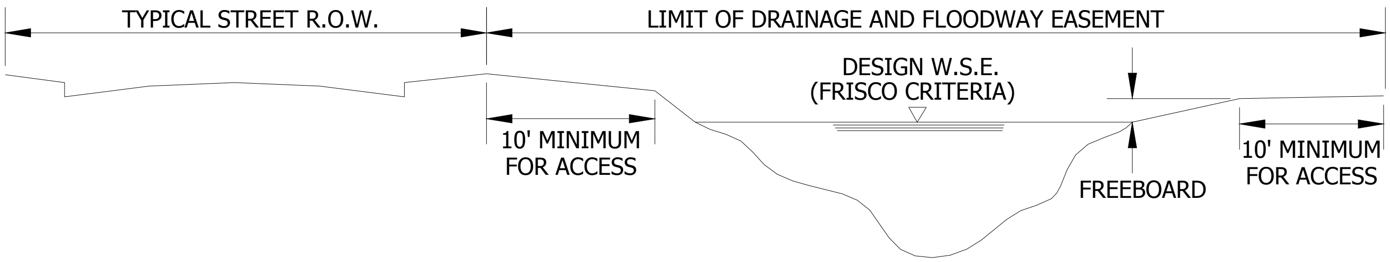
Channel Description	Roughness Coefficient		
	Minimum	Normal	Maximum
Minor Natural Streams			
Moderately Well Defined Channel			
- grass and weeds, little brush	0.025	0.030	0.033
- dense weeds, little brush	0.030	0.035	0.040
- weeds, light brush on banks	0.030	0.035	0.040
- weeds, heavy brush on banks	0.035	0.050	0.060
- weeds, dense willows on banks	0.040	0.060	0.080
Irregular Channel with Pools and Meanders			
- grass and weeds, little brush	0.030	0.036	0.042
- dense weeds, little brush	0.036	0.042	0.048
- weeds, light brush on banks	0.036	0.042	0.048
- weeds, heavy brush on banks	0.042	0.060	0.072
- weeds, dense willows on banks	0.048	0.072	0.096
Flood Plain, Pasture			
- short grass, no brush	0.025	0.030	0.035
- tall grass, no brush	0.030	0.035	0.050
Flood Plain, Cultivated			
- no crops	0.025	0.030	0.035
- mature crops	0.030	0.040	0.050
Flood Plain, Uncleared			
- heavy weeds, light brush	0.035	0.050	0.070
- medium to dense brush	0.070	0.100	0.160
- trees with flood stage below branches	0.080	0.100	0.120
Major Natural Streams			
Moderately Well Defined Channel	0.025	-----	0.060
Irregular Channel	0.035	-----	0.100
Unlined Vegetated Channels			
Mowed Grass, Clay Soil	0.025	0.030	0.035
Mowed Grass, Sandy Soil	0.025	0.030	0.035
Unlined Unvegetated Channels			
Clean Gravel Section	0.022	0.025	0.030
Shale	0.025	0.030	0.035
Smooth Rock	0.025	0.030	0.035
Lined Channels			
Smooth Finished Concrete	0.013	0.015	0.020
Riprap (Rubble)	0.030	0.040	0.050

FIGURE 5.2 – Open Channels

Natural Channel

Creeks may remain in open, natural condition if all of the following conditions are met:

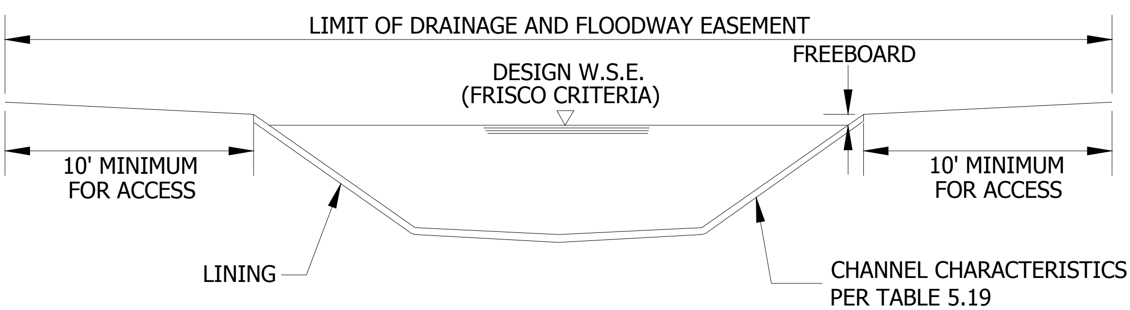
- They comply with the Subdivision Ordinance;
- Tree and vegetative cover is acceptable to the City of Frisco;
- Unsanitary or unacceptable drainage conditions do not exist in the creek;
- Approved by the Director of Engineering Services.
- Meets all State and Federal requirements.



Notes:

- For slopes exceeding 3:1, fifteen feet (15’) of access shall be provided at the top of the slope.
- For slopes exceeding 3:1 within thirty feet (30’) of a roadway or driveway, a guardrail shall be provided.
- A parallel street is recommended on at least one side of a natural channel if it is dedicated to public use.

Excavated Channel



Notes:

- For slopes exceeding 3:1, fifteen feet (15’) of access shall be provided at the top of the slope.
- For slopes exceeding 3:1, fencing shall be provided and constructed with materials approved by the City.
- For slopes exceeding 3:1 within thirty feet (30’) of a roadway or driveway, a guardrail shall be provided.
- Channels with a non-erodible surface shall have a two foot (2’) toe into the ground at the top of slope.
- Channel bottoms shall have a cross slope of one inch (1”) per foot if the base greater than twenty feet (20’) wide.
- Channel bottoms shall be flat if the base is less than twenty feet (20’) wide.
- A maximum depth of ten feet (10’) is recommended.

5.10 MISCELLANEOUS DRAINAGE:

A. Lot Drainage:

1. Lot to lot surface drainage is not allowed in a residential subdivision.

2. There will not be any drainage allowed to flow from a non-residential lot to a residential lot.

3. Residential lots shall be graded to provide a minimum slope of five percent (5%) in the first five feet (5′) from the foundation.

B. Storm Sewer Materials:

1. All City of Frisco mandated storm sewers shall be reinforced concrete.

2. All storm sewers or detention structures under a fire lane or roadway shall be reinforced concrete.

C. The minimum finished floor elevation for any lot adjacent to a drainage channel shall be two feet (2′) above the adjacent one hundred (100) year fully developed water surface elevation and shall be shown on the final plat.

D. Curbs shall be placed along the edge of any alley that is adjacent to a waterway.

E. No portion of any residential lot will be allowed in the fully developed one hundred (100) year floodplain.

F. Reference City of Frisco Benchmarks on the plan view of every drainage sheet.

G. Required mitigation under Section 404 of the Clean Water Act must be called out in the engineering plans.

5.11 ENERGY DISSIPATORS:

A. Energy dissipators are used to eliminate erosive velocities. Effective energy dissipators must be able to retard the flow of fast moving water without damaging the structure or the channel below the structure.

B. Impact-type energy dissipators direct the water into an obstruction (baffle) that diverts the flow in many directions to reduce energy. Baffled outlets and baffled aprons are two impact type energy dissipators. Impact-type energy dissipators should be assured of a low-flow outfall.

C. Other energy dissipators use the hydraulic jump to dissipate excess energy. In this type of structure, water moving in supercritical flow is forced into a hydraulic jump when it encounters a tailwater condition equal to conjugate depth. Stilling basins are structures of this type where the flow plunges into a pool of water created by a weir or sill placed downstream of the outfall.

D. Baffled aprons are used to dissipate the energy in the flow over an apron. The baffle blocks are constructed on the sloping surface of the apron. The channel bottom downstream of the apron must be lined.

E. Impact-type energy dissipators are generally considered to be most effective for outfalls of enclosed storm drainage systems. They also tend to be smaller and more economical structures. Baffled aprons and stilling basins are most frequently used downstream of a spillway or drop structure.

F. All energy dissipators should be designed to facilitate future maintenance. The design of outlet structures in or near parks or residential areas must give special consideration to appearance and shall be approved by the Director of Engineering Services.

5.12 RETAINING WALL IN WATERWAYS:

A. All retaining structures/walls located within a one hundred (100) year floodplain in the City of Frisco shall be constructed of reinforced concrete or other materials approved by the Director of Engineering Services, and shall be designed for the specific onsite conditions by a Licensed Professional Engineer. Structural designs shall be submitted with supporting calculations.

B. Retaining walls shall be designed to achieve a minimum factor of safety of two (2) against overturning and one and a half (1.5) against sliding.

5.13 BRIDGE DESIGN HYDRAULICS:

A. The City of Frisco requires that head losses and depth of flow through bridges be determined with a HEC computer program or other approved program. The following guidelines pertain to the hydraulic design of bridges:

1. Design water surface must not be increased upstream.

2. Excavation of the natural channel is not allowed as compensation for loss of conveyance.

3. Channelization upstream or downstream of the proposed bridge will normally only be permitted when necessary to realign the flow to a more efficient angle of approach.

4. All bridge hydraulics shall be submitted to the City of Frisco for review and approval.

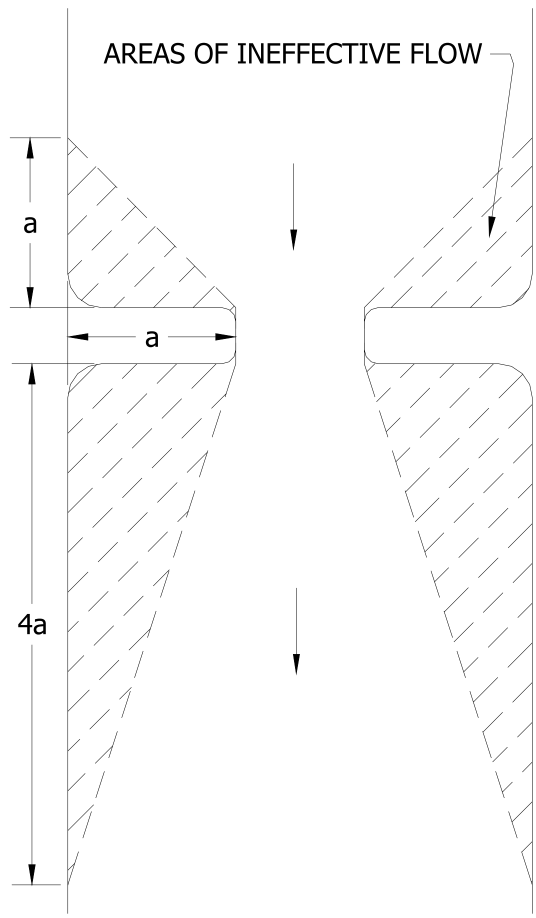
5. Side swales may be used to provide additional conveyance downstream of and through bridges.

6. Bridges are to be designed with the lowest point (low beam) at least two feet (2’) above the water surface elevation of the design storm.

5.14 FLOODPLAIN ALTERATIONS:

A. No new construction is allowed in floodplain areas, but construction is allowed in those areas that have been reclaimed from the floodplain. The City of Frisco has adopted a "natural floodway" that differs from the "regulatory floodway" established by FEMA. The "natural floodway" consists of the natural channel and floodplain that is effective in conveying the design flood. Areas of ineffective flow around bridges, topographic constrictions, and other constrictions are excluded from the "natural floodway". The effective flow area and limits of the "natural floodway" are determined using 4:1 flow expansions downstream of constrictions and 1:1 flow contractions upstream of constrictions. Figure 5.3 displays an example of effective flow areas at a typical bridge location.

FIGURE 5.3 – Effective Flow Areas at Typical Bridge Location



B. Floodplain alteration shall be allowed only if all the following criteria are met:

1. Flood studies must include flows generated for existing conditions and fully-developed conditions for the one hundred (100) year design flood.

2. Alterations of the floodplain and "natural floodway" shall not increase the water surface elevation of the design flood of the creek on other properties.

3. Alterations shall be in compliance with FEMA guidelines.

4. Alterations of the floodplain shall not create or increase an erosive water velocity on or off-site.

5. Alterations shall result in a zero percent (0%) loss of valley storage for a Major Creek, as defined by the Subdivision Ordinance, and a fifteen percent (15%) maximum loss of valley storage for any other tributary for any reach, except at bridge and culvert crossings where it can be proven that there are no detrimental effects downstream.

6. The effects of existing improvements or public and private improvements for which a future commitment has been made by the City of Frisco or county, state, or federal agencies, shall be used in determining water surface elevations and velocities.

7. Any alteration of floodplain areas shall not cause any additional expense in any current or projected public improvements, including maintenance.

8. The floodplain shall be altered only to the extent permitted by equal conveyance on both sides of the natural channel, as defined by the United States Army Corps of Engineers in a HEC analysis. The right of equal conveyance applies to all owners and uses, including greenbelt, park areas, and recreational areas. Owners may relinquish their right to equal conveyance by providing a written agreement to the City of Frisco.

9. Maximum slopes of filled areas shall not exceed 3:1. Fill slopes, vertical walls, terracing, and other slope treatments may be considered provided no unbalancing of stream flow results and only as a part of a grading permit application.

10. A grading permit shall be required so that proper provisions for protecting against erosion losses will be made.

11. The toe of any fill shall parallel the natural channel to prevent an unbalancing of stream flow in the altered floodplain.

12. Engineering plan submission shall include the following plans which shall be specifically approved by the City's Environmental Engineer:

    a. Erosion control of cut and fill slopes.

    b. Restoration of excavated areas.

    c. Tree protection where possible in and below fill area.

C. The above criteria shall be met before any floodplain alteration can be allowed for a proposed project. Typical projects requiring a floodplain alteration include placing fill whether or not it actually raises the property out of the floodplain, constructing a dam, straightening channel sections, making improvements, substantial or otherwise, to existing structures in a floodplain in which the existing outside dimensions of the structure are increased, and temporary storage of fill materials, supplies and equipment.

D. In general, the information needed for the application can be obtained by running a backwater model, such as HEC-2 or HEC-RAS, and a flood routing model, such as TR-20, HEC-1, or HEC-HMS. Both models shall be run by the applicants. The backwater information shall be used to determine that upstream water surface elevations and erosive velocities have not increased. Flood routing information shall be used to insure that the cumulative effects of the reduction in floodplain storage of floodwater will not cause downstream increases in water surface elevations and erosive velocities.

E. A review fee of one thousand dollars ($1000) will be included with each submission. Multiple submissions may be required for a project.

F. Verification of Floodplain Alterations:

    1. Prior to final acceptance by the City for areas involving floodplain alterations or adjacent to defined floodplains, creeks, channels and drainage-ways, a certified statement shall be prepared by a Licensed Professional Engineer showing that all lot elevations, as developed within the subject project, meet or

exceed the required minimum finished floor elevations shown on the alteration plans. This certification shall be filed with the Director of Engineering Services.

2. In addition, at any time in the future when a building permit is desired for existing platted property which is subject to flooding or carries a specified or recorded minimum finished floor elevation, a Registered Professional Land Surveyor shall survey the property prior to obtaining a building permit. The certified survey data showing the property to be at or above the specified elevation shall be furnished to the Director of Engineering Services for approval. Certification of compliance with the provisions of this ordinance pertaining to specified finished floor elevations shall be required.

3. The owner/developer shall furnish, at his expense, to the Director of Engineering Services sufficient engineering information to confirm that the minimum finished floor elevations proposed are as required by this ordinance. Construction permits will not be issued until a Conditional Letter of Map Revision (CLOMR) or amendment has been submitted to FEMA. Letters of Map Revision shall be submitted to FEMA prior to final acceptance of the project. The home builder shall supply to the Director of Engineering Services all necessary documentation and fees to be forwarded to FEMA for application for a Letter of Map Amendment if the Letter of Map Revision has not yet become effective.

5.15 DETENTION DESIGN:

A. Storm water detention is required to temporarily impound (detain) excess storm water, thereby reducing peak discharge rates. This detention is required by City ordinance.

B. The following is a minimum criteria for detention basins within the City of Frisco. Criteria established by the State of Texas for dam safety and impoundment of state waters shall apply where required by the state, and where, in the engineer’s judgment, the potential hazard requires these more stringent criteria.

C. Detention is required for any runoff that exceeds the single family runoff rate (C = 0.55) for 2, 5, 25, and 100 year storms.

D. Offsite drainage flows shall not pass through or be detained in a downstream detention pond unless a written agreement among all property owners involved is provided to define the responsible parties for maintenance of the pond.

1. <u>Detention Storage:</u>

a. Basins without upstream detention areas and with drainage areas of two hundred (200) acres or less can be designed using the Modified Rational Method. This method estimates peak rates using the rational Equation and storage requirements using inflow minus outflow hydrograph volume at the time of peak outflow.

b. Basins with drainage areas greater than two hundred (200) acres or where the Modified Rational Method is not applicable are to be designed using the Unit Hydrograph Method. The design hydrograph routings through the detention basin are to be done using a nationally accepted computer-modeling program approved by the Director of Engineering Services.

c. No required parking space may be located within a surface drainage pond.

d. The following example shall be provided for each of the 2, 5, 25, and 100 year storm events to determine the required detention storage:

GIVEN: A 10-acre site is currently used for agricultural purposes and is to be developed as a retail site. The entire site is the drainage area for the proposed detention basin.

DETERMINE: Maximum release rate and required detention storage.

SOLUTION:

1.) Determine 100-year peak runoff rate for single family runoff (Q=C*I*A). This is the maximum release rate from the site after development. (Any area within the drainage area not being conveyed to the detention basin shall be accounted for in the calculation for the maximum release rate.)

Single Family Conditions:	C	=	0.55
	T_c	=	15 minutes
	I_{100}	=	7.52 inches / hour
	A	=	10 acres
	Q_{100}	=	0.55*7.52*10 = 41.36 cfs

2.) Determine inflow Hydrograph for storms of various durations in order to determine maximum volume required with maximum release rate calculated in step 1. (Incrementally increase durations by 10 minutes until the duration of peak inflow is less then the maximum release rate or where the required storage is less than the storage for the prior duration. The prior duration storage shall be used for the required detention storage.)

Proposed Conditions:	C	=	0.90
	T_c	=	10 minutes
	I_{100}	=	8.74 inches / hour
	A	=	10 acres
	Q_{100}	=	0.90*8.74*10 = 78.66 cfs

Check various duration storms:

10 minutes	I=8.74;	Q=0.9(8.74)10	=	78.66	cfs
20 minutes	I=6.80;	Q=0.9(6.80)10	=	61.20	cfs
30 minutes	I=5.75;	Q=0.9(5.75)10	=	51.75	cfs
40 minutes	I=5.00;	Q=0.9(5.00)10	=	45.00	cfs
50 minutes	I=4.45;	Q=0.9(4.45)10	=	40.05	cfs
60 minutes	I=4.00;	Q=0.9(4.00)10	=	36.00	cfs
70 minutes	I=3.63;	Q=0.9(3.63)10	=	32.67	cfs
80 minutes	I=3.32;	Q=0.9(3.32)10	=	29.88	cfs
90 minutes	I=3.05;	Q=0.9(3.05)10	=	27.45	cfs

Maximum Detention Storage Volume is determined by deducting the volume of runoff released during the time of inflow from the total inflow for each storm duration:

10 minute storm

INFLOW	=	10(78.66)60 sec/min	=	47,196	cf
OUTFLOW	=	(0.5)20(41.36)60 sec/min	=	24,816	cf
STORAGE	=	INFLOW - OUTFLOW	=	22,380	cf

20 minute storm

INFLOW	=	20(59.40)60 sec/min	=	73,440	cf
OUTFLOW	=	(0.5)30(41.36)60 sec/min	=	37,224	cf
STORAGE	=	INFLOW - OUTFLOW	=	36,216	cf

30 minute storm

INFLOW	=	30(51.75)60 sec/min	=	93,150	cf
OUTFLOW	=	(0.5)40(41.36)60 sec/min	=	49,632	cf
STORAGE	=	INFLOW - OUTFLOW	=	43,518	cf

40 minute storm

INFLOW	=	40(45.00)60 sec/min	=	108,000	cf
OUTFLOW	=	(0.5)50(41.36)60 sec/min	=	62,040	cf
STORAGE	=	INFLOW - OUTFLOW	=	45,960	cf

50 minute storm

INFLOW	=	50(40.05)60 sec/min	=	102,150	cf
OUTFLOW	=	(0.5)60(41.36)60 sec/min	=	74,448	cf
STORAGE	=	INFLOW - OUTFLOW	=	45,702	cf

60 minute storm

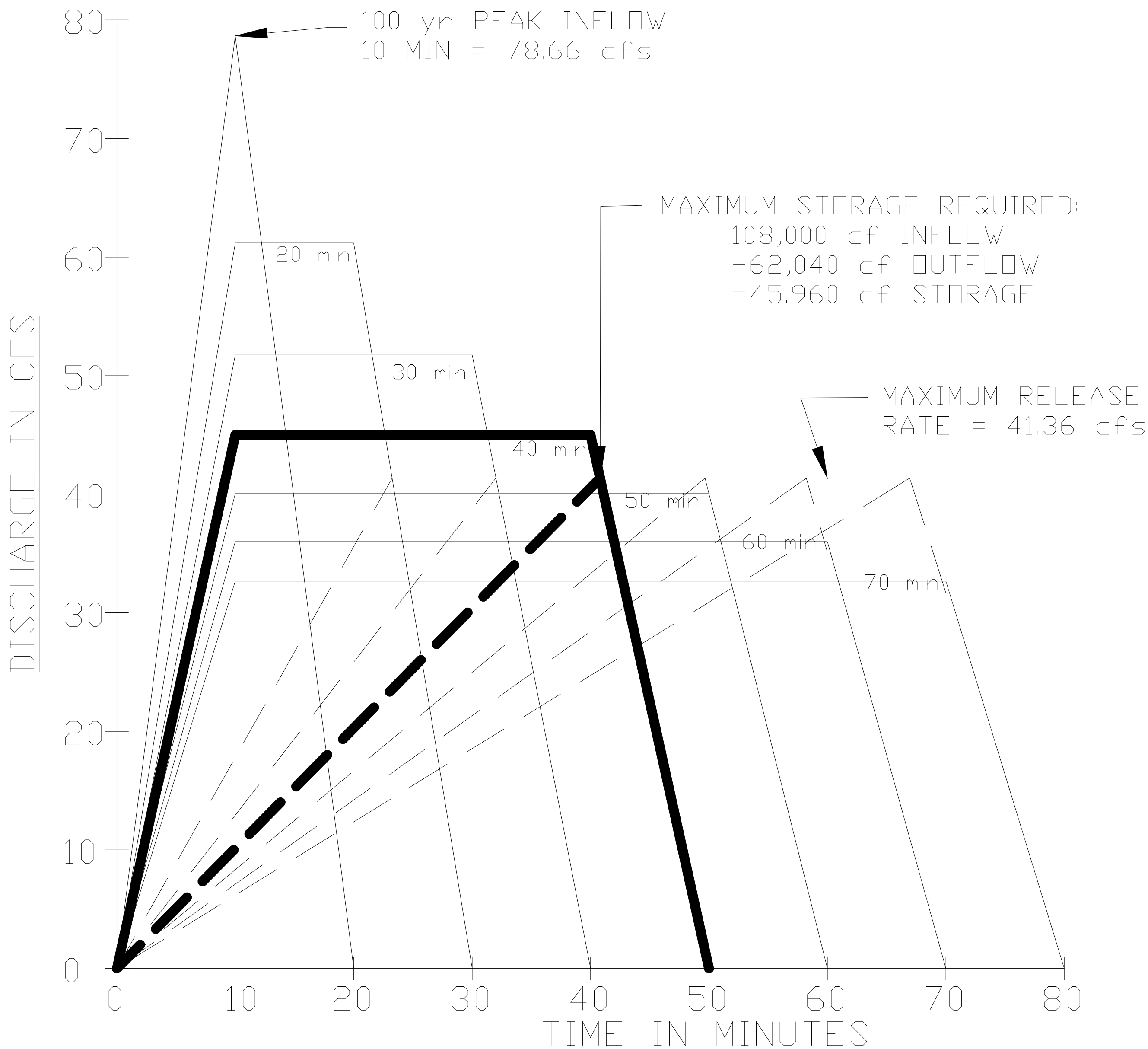
INFLOW	=	60(36.00)60 sec/min	=	129,600	cf
OUTFLOW	=	(0.5)70(41.36)60 sec/min	=	86,856	cf
STORAGE	=	INFLOW - OUTFLOW	=	42,744	cf

70 minute storm

INFLOW	=	70(32.67)60 sec/min	=	137,214	cf
OUTFLOW	=	(0.5)80(41.36)60 sec/min	=	99,264	cf
STORAGE	=	INFLOW - OUTFLOW	=	37,950	cf

Required detention storage is 45,960 cf at the 40 minute storm duration.
The inflow hydrograph for storms of various durations is shown in Figure 5.4.

FIGURE 5.4 – Inflow Hydrograph



2. Freeboard and Emergency Spillway:

   a. Where earth embankments are used to temporarily impound the required detention, the top of the embankment will be a minimum of two feet (2′) above the maximum one hundred (100) year pool level. In addition, an emergency spillway or overflow area will be provided at the maximum one hundred (100) year pool level to ensure that the five hundred (500) year frequency event does not overtop the embankment.

   b. Non-embankment detention structures shall have a minimum of one foot (1′) of freeboard above the one hundred (100) year water surface elevation.

   c. The emergency spillway needs to be designed to pass the peak runoff for a five hundred (500) year storm. It must be structurally designed to prevent erosion and consequent loss of structural integrity.

   d. The minimum width for a vegetated earth spillway is four feet (4′).

3. Outflow Structure – Where the outflow structure conveys flow through the embankment in a conduit, the conduit shall be reinforced concrete designed to support the external loads with an adequate factor of safety. It shall withstand the internal hydraulic pressures without leakage under full external load or settlement. It must convey water at the design velocity without damage to the interior of the conduit.

4. Embankment Design: – The steepest side slope permitted for a vegetated embankment is 4:1 and 2:1 for rock dam. The minimum crown width is provided in Table 5.21.

TABLE 5.21 – Minimum Crown Widths for Embankments

Total Height of Embankment (Feet)	Minimum Crown Width (Feet)
14 or less	8
15 - 19	10
20 -24	12
24 -34	14

5. Underground Storage – Underground detention basins are permitted provided that they have some means to allow for them to be cleaned of silt and debris by the property owner and that they be constructed of reinforced concrete if located under any fire lane.

6. Basin Grading – Detention basins to be excavated must provide positive drainage with a minimum grade of three-tenths of a percent (0.3%). The steepest side slope permitted for an excavated slope not in rock is 4:1.

7. Earth Embankment Specifications – Earth embankments used to impound required detention volume must be constructed according to specifications as required based on geotechnical investigations of the site and all regulatory requirements (i.e. embankments over six feet (6′) must be approved by TCEQ).

8. Maintenance Provisions – Access must be provided in detention basin design for periodic desilting and debris removal. Basins with permanent storage must address dewatering procedures for maintenance. Detention basins with a drainage area of three-hundred twenty (320) acres or more must include a desilting basin for the upstream pool area.

9. Safety – Any slope that exceeds 3:1 shall have pedestrian rails or fencing next to the basin. Any surface detention basin adjacent to a paved surface will have permanent vehicular barricades.

5.16 EROSION AND SEDIMENTATION CONTROL:

A. All projects shall be designed so that erosion is minimized during construction as well as after the construction is completed. The volume, rate, and quality of storm water runoff originating from development must be controlled to prevent soil erosion. Specific efforts shall be made to keep sediment out of street and watercourses.

B. All projects requiring grading or clearing of more than one (1) acre must submit a two-phase erosion/sedimentation control plan: one for construction and one for post construction. The construction phase of the plan must show on a topographic map the features and soil characteristics of the site, which indicate the land's erosive potential. This plan shall describe proposed control measures and how the control sequence is interfaced with the construction schedule.

C. The post-construction plan shall describe measures and schedules for restoring disturbed areas and preventing erosion and sedimentation after construction. Control measures could include soil cover, water barriers, filter strips, or other types of stabilization and interception. If vegetative cover is employed, other control methods shall continue until vegetative cover is firmly established.

D. The owner is responsible for maintenance of erosion and sedimentation control measures and must remove sediment from City right-of-way or storm drainage systems that occur during the construction phase.

5.17 DRAINAGE EASEMENTS:

A. The following minimum width exclusive drainage easements are required when facilities are not located within public rights-of-way or easements:

1. Storm sewers are to be located within the center of a fifteen foot (15′) drainage easement or 1.5 times the depth plus the width of the structure rounded up to the nearest five feet (5′), whichever is greater.

2. Overflow flumes are to be located with the edge being a minimum of one foot (1′) off the property line within a ten-foot (10′) drainage easement.

3. In residential developments, storm sewer mains shall not cross residential lots unless specifically approved by the Director of Engineering Services, in which case the easement shall be located within a single lot.

4. Easements for channels will be the top of the bank plus ten feet (10′) feet for access if the channel side slope is less than 3:1 and fifteen feet (15′) if it is steeper than 3:1.

5. Drainage easements shall be dedicated to the City of Frisco when the drainage system crosses a property line.

6. Drainage and Floodway Easements shall be dedicated for all floodplains and shall include an erosion hazard setback to reduce the potential for damage due to erosion of the bank.

7. Drainage and Detention Easements shall be dedicated for all detention facilities.

8. All easements shall be dedicated by plat or replat. Separate instrument easements shall only be allowed on property that is not part of the proposed development and has not been previously platted. Conveyance Plats must be revised if an easement is added or altered and shall then be recorded with the County.